REFRIGERANT COMPOSITION

This invention relates to refrigerant compositions which have no adverse effect on stratospheric ozone and to compositions which are for use both in refrigeration and air conditioning systems designed to use Ozone Depleting Substances (ODS) CFC12 (dichlorodifluoromethane), CFC502 (azeotrope of chloropentafluoromethane and chlorodifluoromethane)) and HCFC22 (chlorodifluoromethane) and additionally in new equipment. These new refrigerant compositions are compatible with lubricants commonly found in refrigeration and air conditioning systems.

The compositions may also be used in equipment designed for non ozone depleting substances.

It is well known that chlorofluorocarbons (CFCs) such as CFC12 and CFC502 and hydrochlorofluorocarbons such as HCFC22 while being energy efficient, non flammable and of low toxicity migrate to the stratosphere where they are broken down by ultra violet light to attack the ozone layer. These Ozone Depleting Substances are in the process of being replaced by non ozone depleting alternatives such as hydrofluorocarbons (HFCs) which are also non flammable, efficient and of low toxicity. There are six main HFCs, namely HFC134a, HFC32, HFC125, HFC143a, HFC227ea and HFC152a, which either individually or blended into mixtures can replace CFCs and HCFCs. While HFC134a, HFC227ea and HFC152a can be used to replace ODS directly, HFC32, HFC143a, and HFC125 are generally found in blends as replacements for ODS.However, HFCs do not have adequate solubility in traditional lubricants such as mineral and alkylbenzene oils so that synthetic oxygen containing lubricants have been introduced specifically for new equipment. These new lubricants are expensive and hygroscopic.

Refrigerant blends such as R404A, R507, R410A, R407C and others have been commercialised as replacements for CFCs and HCFCs but, because these compositions contain only HFC components, they cannot be used with the traditional lubricants commonly found in use with CFCs and HCFCs. If these blends are to be used to replace CFCs and HCFCs in existing equipment, the major chemical manufacturers recommend that no more than 5% of the traditional lubricant in the system be retained so that a virtual complete change of lubricant to a synthetic oxygen containing lubricant resulting in a full retrofit is required, which is often costly and technically unsatisfactory..

Although equipment manufacturers have adapted their units to operate with HFC blends, they do not always find the commercially available products as satisfactory as the CFCs and HCFCs that these new refrigerants are replacing. In particular to ensure adequate oil return, hydrocarbon lubricants, such as mineral oil, have been replaced by oxygen containing lubricants, notably polyol esters and polyalkylene glycols. Unfortunately these materials are liable to absorb atmospheric moisture, especially during maintenance, which can contribute to excessive corrosion and wear in equipment thus reducing its reliability. A key objective of this patent is to provide HFC/hydrocarbon blends that enable the continued use of hydrocarbon oils in both existing and new equipment.

Additionally some refrigerants, such as R07C, have wide temperature glides (> 4°C) in the evaporator and condenser, whereas equipment manufacturers, based on their experience with CFC/HCFC single fluids or azeotropes, prefer refrigerants with low glides. A further key objective of this invention, therefore, is to provide HFC/hydrocarbon blends that can substitute for CFC 12, HCFC 22 and azotrope 502 (CFC 115/HCFC 22) both allowing the continued use of hydrocarbon lubricants in equipment and minimising the temperature glides in the heat exchangers.

The present invention relates to refrigerant compositions, which are non flammable under all conditions of fractionation as defined under ASHRAE Standard 34, and which can be used to replace ODS in an existing unit without the need to change the lubricant or make any significant change to the system hardware. In new equipment the refrigerant compositions allow the continued use of hydrocarbon oils, although the manufacturers may take the opportunity to modify their units to optimise the performances of the new refrigerants, for example by selecting the most appropriate lengths of capillary tubes. Where the ingress of moisture or other problems are being experienced with oxygen containing oils the new compositions allow such oils to be replaced by hydrocarbon oils

It is known in the art that the addition of a small amount of hydrocarbon to a refrigerant composition containing an HFC or HFC mixtures can result in sufficient hydrocarbon being dissolved in the lubricant to be transported around the system so that lubrication of the compressor is maintained at all times. It is obvious that the greater the hydrocarbon content of the composition the greater the ability of the refrigerant to transport the lubricant back to the compressor. However, too high a hydrocarbon content can lead to flammable mixtures. Although flammable refrigerants are acceptable in some applications, this invention relates to non flammable compositions for use in equipment where flammable refrigerants are prohibited. However, it is not well understood how to achieve non flammable compositions under all conditions including fractionation of the refrigerant compositions which can take place during a leak of the refrigerant from the system or during storage.

Not all HFCs are non flammable as defined under ASHRAE Standard 34. HFC143a and HFC32 have not received a non flammable rating by ASHRAE. This invention relates to compositions of refrigerants which not only covers blends of non flammable HFCs with hydrocarbons but also blends of flammable HFCs, non flammable HFCs and hydrocarbons in selected proportions such that all such compositions are non

flammable during fractionation while providing similar refrigerating effects and thermodynamic performances as the ODS they replace, namely CFC12, CFC502 and HCFC22.

While this invention relates to refrigerant compositions which can be used with traditional lubricants such as mineral and alkylbenzene oils, they are also suitable for use with synthetic oxygen containing lubricants.

In formulating HFC/hydrocarbon blends to replace CFC 12, CFC 502 and HCFC 22 in specific applications it is generally necessary to use one or more lower boiling HFCs, with one or more higher boiling HFCs. In this context preferred lower boiling HFCs are HFC 32, HFC 143a and HFC 125, and higher boiling HFCs are HFC 134a, HFC 134, HFC 227ea and HFC 152a.

To avoid flammability in the blend, or in a fraction generated by a leak, for example as defined by ASHRAE Standard 34, the total amount of hydrocarbon should be minimised. At the same time the quantity of the hydrocarbon mixture dissolved in the oil needs to be maximised for good oil return, especially at those locations in the circuit where the oil is at its most viscous, for example the evaporator. A single higher boiling hydrocarbon, such as pentane or *iso*-pentane, would certainly show higher solubility in the oil than a lower boiling hydrocarbon. However, as the result of a leak, for example from a cylinder, a higher boiling hydrocarbon will concentrate in the liquid phase. The amount of hydrocarbon will, therefore, need to be limited in order to avoid generating a flammable mixture towards the end of the leak.

This problem could be avoided by using only a low boiling hydrocarbon such as propane or *iso*-butane. However, this has 2 disadvantages. Firstly, lower boiling hydrocarbons are less soluble than higher boiling hydrocarbons in hydrocarbon lubricants in the evaporator when present at similar weights % as formulated in the blend. Consequently they are less effective at ensuring good oil return. Secondly,

because of their higher volatility they tend to concentrate in the vapour phase of a blend. Their concentration therefore needs to be restricted to avoid generating flammable mixtures at the beginning of a leak. This problem is exacerbated if the one or more of the lower boiling HFCs is also flammable.

Surprisingly we have found that the best approach to formulating HFC/HC refrigerant blends is to use combinations of two and preferably three hydrocarbons with different boiling points. This allows the total amount of hydrocarbon of the blend to be reduced while simultaneously the amount dissolved in the oil in the evaporator is increased.

This invention has the following advantage. Hydrocarbon components facilitate oil return, but, because of their flammability, restrict the weights of flammable HFCs, notably HFC 143a that can be included. Inclusion of these fluids can be valuable in achieving the required balance of thermodynamic properties, so minimising the amounts of hydrocarbon present allows more scope in formulating preferred blends.

The blending of HFCs to achieve the desired balance of physical properties appropriate to various cooling applications is well known and a variety of products are available commercially, for example R407C, R410A and R410B. Although these have been selected for specific applications in combination with oxygen containing synthetic lubricants, simply adding 2 or 3 hydrocarbon components to these products does not achieve the preferred products for use with hydrocarbon lubricants. Firstly, the hydrocarbon components contribute to the overall thermodynamic properties of the blend so will affect the preferred ratios of the HFCs. Secondly, the ratio of flammable to non-flammable HFCs will need to selected to ensure non-flammability, for example, as required by the ASHRAE 34 Standard.

Blends of HFC125, HFC134a, HFC143a, HFC227ea are particularly preferred as replacements for CFCs and HCFCs. Both HFC125 (pentafluoroethane) and R227ea are non flammable under all operating conditions and in addition are fire suppressants,

an application for which they have been developed by the fire fighting industry. The presence of HFC227ea provides a twofold advantage of reducing the flammability of the composition and also enhances oil return to the compressor due to emulsification of the lubricant in the presence of a hydrocarbon.

Blends of HFC134a, HFC227ea, HFC125 and mixtures of selected hydrocarbon additives have been found to be preferred replacements for CFC12 in centrifugal chillers. It has been found that the interaction of hydrocarbon additives in such mixtures facilitates non flammable mixtures during all conditions of leakage during fractionation so that non flammability can be achieved according to ASHRAE Standard 34. The presence of hydrocarbons results in the lubricant being returned to the compressor. The presence of R227ea enables the requisite molecular weight of the blend to match that of CFC12 and additionally facilitates non flammability due to its fire retardant properties. The presence of R125 increases the capacity of the blend. The resulting mixtures are a close match for CFC12 in thermodynamic and system performance.

Surprisingly it has been found that given the same percentage content of hydrocarbon additive in the refrigerant composition, increasing the HFC125 content of the composition results in flammable mixtures being created during fractionation. This is very surprising since it would seem obvious that the greater the amount of HFC125 in the composition the less would be the likelihood to generate a flammable mixture during fractionation The reasons for this apparent anomaly relate to the pressure/temperature relationship between the quantities of HFC125 and HFC134a in the mixture and the amount and type of hydrocarbon and/or hydrocarbon mixture. The following refrigerant compositions were made up and leaked away until the cylinder was almost liquid empty according to ASHRAE Standard 34:

	%	
	Blend 1	Blend 2
R134a	48.0	21.0
R125	49.0	76.0
butane	2.7	2.5
isopentane	0.3	0.5

Blend 2 with the considerably higher HFC125 content was found to create a flammable composition during fractionation, while Blend 1 with a lower HFC125 content remained non flammable throughout fractionation.

In GC 2727427 N A Roberts teaches that, if a hydrocarbon with at least four carbon atoms other than methyl propane (isobutane) is used, surprisingly the flammability of the fractionated composition is greatly reduced. Surprisingly, we have now found that the inclusion of isobutane with appropriately chosen hydrocarbons does not result in flammable compositions during fractionation. It has been found that the selection of the hydrocarbon additive or mixtures thereof with the HFC components is critical to achieving non flammability under all operating conditions and as defined under ASHRAE Standard 34.

In US5,800,730 it is stated that HFC 134a needs to be added to blends of HFC125 and HFC143a as a replacement for CFC502 in order to avoid a flammable mixture (example 3). Surprisingly we have found that by excluding HFC134a, changing the proportion of HFC125 to HFC143a and adding a selected range of hydrocarbons results in a composition which is non flammable during fractionation and a close match for R502 with regard to thermodynamic performance.

In US5,211.867, azeotropic compositions are claimed of R125 and R143a. It is a key feature of this invention that a specially selected hydrocarbon or mixtures of hydrocarbons are present in order to facilitate oil return to the compressor. Surprisingly it has been found that, despite the flammability of HFC143a, the selection of a hydrocarbon or mixtures of hydrocarbons enables the compositions to be non flammable during fractionation. The combination of a high boiling hydrocarbon such as isopentane (BP 27°C) with butane (BP -0.5°C) and isobutane (BP -11.5°C) avoids build up of hydrocarbon content in the liquid phase during a leakage while the more volatile isobutane is countered in the vapour phase by the fire suppressant HFC125 due to the latter's higher vapour pressure and lower boiling point (BP -45°C). In order for the composition to be non flammable, the HFC125 content of the composition is above the azeotropic composition so that the content of HFC143a is reduced but without affecting the refrigerating performance of the composition as a replacement for CFC502.

Although the addition of hydrocarbons to HFCs has been previously described, it has not been previously appreciated that the volatilities of the hydrocarbons need to be matched to the application for which the refrigerant is intended. For example R12 is employed as the refrigerant in domestic freezers with evaporating temperatures of ~-22°C, in domestic fridges with evaporating temperatures of ~-5°C, and in mobile air conditioning with evaporating temperatures of ~5°C. An important aspect of this invention is to formulate HFC/HC blends that ensure good oil return in these disparate applications while also ensuring that the refrigerant blend remains non-flammable according to the chosen criterion. For applications with evaporators operating at temperatures above -5°C the higher boiling hydrocarbons are preferred. Specially preferred are isopentane, alone or mixed with butane. For applications with the evaporators operating in the range -20°C to -5°C mixtures of hydrocarbons containing a higher, an intermediate and a lower boiling point component are preferred. Especially preferred are blends containing isopentane, butane and isobutane. For evaporators operating below -20°C HC mixtures containing isobutane and butane are preferred with optionally some isopentane.

According to the present invention a refrigerant composition consists essentially of a combination of a hydroflurocarbon component consisting of a combination selected from the following mixtures:

      (1)   R134a and R125;

      (2)   R134a, R125 and R143a

      (3)   R125 and R143a

      (4)   R134a, R227ea and R125

and a hydrocarbon component consisting essentially of a combination selected from the following mixtures:

      (5)   isopentane and butane

      (6)   isopentane, butane and isobuttane

      (7)   butane and isobutane.

In preferred embodiments the composition consists of a mixture of one hydrofluorocarbon component and one hydrocarbon component so that no substantial amount of any other components or other gases are present.

In a first preferred embodiment the hydrocarbon is present in an amount of 0.6 to 4% and wherein the composition is non-flammable when completely in the vapour phase.

In a second preferred embodiment the hydrocarbon is present in an amount of 0.6 to 4% and wherein when the composition is in a container both vapour and liquid present, neither vapour nor liquid phase is flammable.

In a third preferred embodiment the hydrocarbon is present in an amount of 0.6 to 4% and wherein at any time during a leak from a vapour space in a container neither the liquid phase nor the vapour phase is flammable.

In a fourth preferred embodiment the hydrocarbon is present in amount of 0.6 to 4% and wherein at any time during a leak from a liquid space in a container neither the liquid phase nor vapour phase is flammable.

According to a fifth preferred embodiment the hydrocarbon is present in an amount of 0.6 to 4% and wherein the proportion of hydrocarbon to hydrofluorocarbon in the vapour phase does not differ from the equivalent proportion in the liquid phase by more than 40%, more preferably not by more than 30%, most preferably not by more than 20% at equilibrium at 25°C.

In a sixth preferred embodiment hydrocarbon is present in amount of 0.6 to 4% and wherein the proportion of hydrocarbon to hydrofluorocarbon in the vapour phase does not differ from the formulated composition by more than 40%, preferably by not more than 30%, most preferably by not more than 20% at equilibrium at 25°C.

In particularly preferred compositions in accordance with either the fifth or sixth preferred compositions above, during a leak from the vapour space or liquid space in a container, the proportion of hydrocarbon to hydrofluorocarbon in either of the vapour phase or the liquid phase does not differ from the formulated composition by more than 40%, more preferably by not more than 30%, most preferably by not more than 20% at equilibrium at 25°C.

Preferred compositions in accordance with this invention meet two or more of the criteria of the preferred embodiment.

In a first aspect of this invention the hydrocarbon component consists of a mixture of isopentane, butane and isobutane.

The amount of isopentane is preferably about 0.6 to 2% or more preferably about 0.6 to 1%.

The amount of butane is preferably about 0.6 to 5%, more preferably about 0.6 to 3%, most preferably about 0.6 to 2%.

The amount of isobutane is preferably about 0.6 to 5%, more preferably about 0.6 to 2%, most preferably about 0.6 to 1%.

In a second preferred aspect the hydrocarbon component consists of a mixture of isopentane and butane.

The isopentane may be present in an amount of 0.6 to 1%, preferably about 0.6%. The amount of butane is preferably about 1.3 to 2.5%, more preferably about 1.4%.

In a third preferred aspect of the invention the hydrocarbon component consists of a mixture of butane and isobutane. The amount of butane is preferably about 0.6 to 5% and the amount of isobutane is about 0.6 to 5%.

A first preferred refrigerant composition which may find application as a replacement or substitute for R12 consists essentially of:

R134a	93.1 to 81.5%
R125	5 – 15%
isopentane	0.6 to 1%
butane	1.3 to 2.5%

A particularly preferred composition consists essentially of:

R134a	93%
R125	5%
isopentane	0.6%
butane	1.4%

A second refrigerant composition which may find application as a replacement or substitute for R12 consists essentially of:

R134a	93.2 to 80%
R125	5 to 15%
isopentane	0.6 to 1%
butane	0.6 to 3%
isobutane	0.6 to 1%

A particularly preferred composition consists essentially of:

R134a	93%
R125	5%
isopentane	0.6%
butane	0.8%
isobutane	0.6%

A preferred refrigerant composition which may find application as a replacement or substitute for R22 consists essentially of:

R134a	53.2 to 39%
R125	45 to 55%
isopentane	0.6 to 1%
butane	0.63%
isobutane	0.62%

A particularly preferred composition consists essentially of:

R134a	47.5%
R125	50%
isopentane	0.6%
butane	1%
isobutane	0.9%

A further refrigerant composition which may find application as a replacement or substitute for R22 consists essentially of:

R134a	10 to 30%
R125	80 to 40%
R143a	10 to 30%
isopentane	0.6 to 2%
butane	0.6 to 5%
isobutane	0.6 to 5%

A particularly preferred composition consists essentially of:

R134a	16.5%
R125	60%
R143a	21%
isopentane	0.6%
butane	0.9%
isobutane	1%

A preferred refrigerant composition which may find application as a replacement or substitute for R502 consists essentially of:

R125	75 to 55%
R143a	25 to 45%
butane	0.6 to 5%

In a particular preferred composition consists essentially of:

R125	60.5%
R143a	37%
butane	1%
isobutane	1.5%

A further preferred composition consists essentially of:

R125	60.5%
R143a	37%
butane	0.9%
isobutane	1%
isopentane	0.6%

A alternative refrigerant composition which may find use as a replacement or substitute for R12 in centrifugal chillers and similar devices consists essentially of:

R134a	58.2 to 36%
R227ea	35 to 50%
R125	5 to 8%
isopentane	0.6 to 2%
butane	0.6 to 2%
isobutane	0.6 to 2%

A particularly preferred composition consists essentially of:

R134a	51%
R227ea	41%
R125	6%
isopentane	0.6%
butane	0.8%
isobutane	0.6%

Percentages and other proportions referred to in this specification are by weight unless indicated otherwise and are selected to total 100% from within the ranges disclosed.

The invention is further described by means of example but not in a limitative sense.

Replacements for R22 in Room Air Conditioning

EXAMPLE 1

Blends comprising fluids selected from R125, R143a, 134a, 600, 600a and 601a.

The performances of various blends were evaluated in a typical static air conditioning cycle using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	7.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	45.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
LIQUID LINE/SUCTION LINE HEAT EXCHANGER	
Efficiency	0.3
COMPRESSOR	
Electric motor efficiency	0.85
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Indoor fan	0.3 kW
Outdoor fan	0.4 kW
Controls	0.1 kW

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Tables 1a and 1b. For comparison the performances of R22 and R407C are also shown.

Table 1a

Refrigerant	R-22	R407C	1	2	3	4	5	6	7	8	9	10
R125 wt%			33	33	38	50	60	33	38	50	60	63
R143a wt%			35	38	40	23	23	40	40	33	23	23
R134a wt%			30	27	20	25	15	25	20	15	15	12
R600			1	1	1	1	1	1.3	1.3	1.3	1.3	1.3
R600a			1	1	1	1	1					
R601a							1	0.7	0.7	0.7	0.7	0.7
Discharge pressure (bar)	17.91	19.30	18.00	18.50	19.01	18.64	19.80	19.21	18.67	19.28	19.42	19.85
Discharge temperature (°C)	104.7	92.5	79.6	79.3	78.8	78.1	76.8	79.0	79.5	78.4	77.6	75.4
COP (system)	2.49	2.47	2.45	2.44	2.43	2.44	2.41	2.42	2.44	2.42	2.42	2.39
Capacity (kW/m3)	3067	3172	2870	2933	2995	2938	3072	3005	2944	3008	3015	3019
Glide in evaporator (°C)	0	4.8	2.4	2.2	2.0	2.4	1.9	3.0	3.2	3.1	3.2	3.8
Glide in condenser (°C)	0	4.7	2.1	2.0	1.8	2.1	1.7	2.5	2.7	2.6	2.7	3.1

WO 2005/083028   PCT/GB2005/000737

18

Table 1b

Refrigerant	R-22	R407C	1	2	3	4	5	6	7	8
R125 wt%			30	33	35	38	39	60	50	40
R143a wt%			23	25	28	30	34	23	30	35
R134a wt%			45	40	35	30	25	15	18	23
R600			1.3	1.3	1.3	1.3	1.3			
R600a			0.7	0.7	0.7	0.7	0.7	1.3	1.3	1.3
R601a								0.7	0.7	0.7
Discharge pressure (bar)	17.91	19.30	16.54	17.01	17.49	17.99	18.48	19.66	19.21	18.61
Discharge temperature (°C)	104.7	92.5	80.2	79.9	79.6	79.2	79.0	77.3	78.2	79.2
COP (system)	2.49	2.47	2.48	2.47	2.46	2.45	2.44	2.41	2.42	2.44
Capacity (kW/m3)	3067	3172	2678	2740	2802	2865	2928	3043	2998	2933
Glide in evaporator (°C)	0	4.8	2.7	2.7	2.6	2.5	2.3	2.8	2.8	2.9
Glide in condenser (°C)	0	4.7	2.5	2.5	2.4	2.3	2.1	2.3	2.3	2.5

Replacements for R12

EXAMPLE 2

Blends comprising fluids selected from R125, R134a, R600, R 600a and R601a

The performances of blends were evaluated in a typical open, air conditioning cycle such as mobile air conditioning (MAC) using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	7.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	60.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
COMPRESSOR	
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Outside fan	0.4 kW

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Table 2. For comparison the performances of R12 and 134a are also shown.

Table 2

Refrigerant	R12	R134a	1	2	3	4	5
R125 wt%			5	7	10	12	15
R134a wt%			92.9	90.9	87.9	85.9	82.9
R600 wt%		.	0.7	0.7	0.7	0.7	0.7
R600a wt%			0.7	0.7	0.7	0.7	0.7
R601a wt%			0.7	0.7	0.7	0.7	0.7
Discharge pressure (bar)	15.72	17.42	17.77	17.97	18.27	18.48	18.80
Discharge temperature (°C)	88.4	84.4	83.9	83.9	83.8	83.8	83.7
COP (system)	2.45	2.38	2.36	2.35	2.35	2.34	2.33
Capacity (kW/m3)	1754	1771	1789	1804	1826	1841	1863
Glide in evaporator (°C)	0	0	0.7	0.9	1.1	1.2	1.4
Glide in condenser (°C)	0	0	0.9	1.1	1.3	1.5	1.7

EXAMPLE 3

Blends comprising fluids selected from R125, R134a, R600 and R601a

The performances of various blends were evaluated in a typical open air-conditioning cycle using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10kW
EVAPORATOR	
Midpoint fluid evaporation temperature	7.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	60.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
COMPRESSOR	
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Outside fan	0.4 kW

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Table 3. For comparison the performances of R12 and 134a are also shown.

WO 2005/083028
PCT/GB2005/000737
22

Table 3

Refrigerant	R12	R134a	1	2	3	4	5	6	7
R125 wt%			1	3	5	5	7	9	12
R134a wt%			97	94.5	93	92.5	91	89	86
R600 wt%			1.4	1.6	1.4	1.6	1.4	1.4	1.4
R601a wt%			0.6	0.9	0.6	0.9	0.6	0.6	0.6
Discharge pressure (bar)	15.72	17.42	17.29	17.38	17.68	17.58	17.88	18.08	18.39
Discharge temperature (°C)	88.4	84.4	83.9	83.9	83.9	83.8	83.8	83.8	83.7
COP (system)	2.45	2.38	2.37	2.37	2.36	2.36	2.36	2.35	2.34
Capacity (kW/m3)	1754	1771	1754	1759	1783	1773	1798	1813	1835
Glide in evaporator (°C)	0	0	0.3	0.6	0.6	0.8	0.8	0.9	1.1
Glide in condenser (°C)	0	0	0.4	0.8	0.8	1.0	1.0	1.2	1.4

EXAMPLE 4

Blends comprising fluids selected from R125, R134a, R227ea, R600, R 600a and R601a

The performances of various blends were evaluated in an hermetic refrigeration cycle typical of that used in a domestic fridge-freezer using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	1 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	-25 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	50.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
COMPRESSOR	
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
Electric motor efficiency	0.85
PARASITIC POWER	
Controls	0.01 kW

The results of analysing the performances in fridge-freezer unit using these operating conditions are shown in Table 4. For comparison the performances of R12 and 134a are also shown.

Table 4

Refrigerant	R12	R134a	1	2	3	4	5
R125 wt%			5	6	8	6	6
R134a wt%			93	92	90	92	92
R227ea						5.7	5.7
R600 wt%			0.6	0.7	0.7		0.6
R601a wt%			0.7	0.6	0.6	0.6	
R600a wt%			0.7	0.7	0.7	0.7	0.7
Discharge pressure (bar)	12.59	13.68	13.97	14.09	14.22	14.25	14.37
Discharge temperature (°C)	96.7	90.5	89.4	89.3	89.2	87.4	87.2
COP (system)	1.56	1.50	1.49	1.48	1.48	1.47	1.47
Capacity (kW/m3)	568	508	515	518	522	517	523
Glide in evaporator (°C)	0	0	0.6	0.7	0.8	0.8	0.6
Glide in condenser (°C)	0	0	0.9	1.0	1.3	1.2	0.9

EXAMPLE 5

Blends comprising fluids selected from R125, R134a, R227ea, R600, R 600a and R601a

The performances of various blends were evaluated in an open cycle typical of that used in a centrifugal chiller using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	1 mW
EVAPORATOR	
Midpoint fluid evaporation temperature	0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	45.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
COMPRESSOR	
Compressor isentropic efficiency	0.7
PARASITIC POWER	0.07 mW

The results of analysing the performances in fridge-freezer unit using these operating conditions are shown in Table 5. For comparison the performances of R12 and 134a are also shown.

Table 5

Refrigerant	R12	R134a	1	2	3	4
R134a wt%		60	55	59	55	55
R227ea wt%		38	43	34	38.6	38
R125 wt%				5	5	5
R601a wt%		0.6	0.6	0.7		
R600 wt%		0.7	0.7		0.7	0.7
R600a wt%		0.7	0.7	1.3	0.7	1.3
Discharge pressure (bar)	11.21	11.42	11.29	11.96	11.97	12.01
Discharge temperature (°C)	84.8	72.5	71.5	73.1	72.1	72.1
COP (system)	1950	1820	1792	1902	1896	1903
Capacity (kW/m3)	2.56	2.51	2.51	2.51	2.50	2.50

Replacements for R 502 in Low Temperature Refrigeration

EXAMPLE 6

Blends comprising fluids selected from R125, R143a, R134a, R227ea, R600a, R600 and R600a

The performances of various blends were evaluated in hermetic refrigeration cycle typical of that used in some frozen cabinets using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	-35 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	35.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
LIQUID LINE/SUCTION LINE HEAT EXCHANGER	
Efficiency	0.3
COMPRESSOR	
Electric motor efficiency	0.85
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Internal and defrost	0.3 kW
External fan	0.4 kW
Controls	0.1 kW

The results of analysing the performances in fridge-freezer unit using these operating conditions are shown in Table 6. For comparison the performances of R12 and 134a are also shown.

Table 6

Refrigerant	R502	R22					
R125 wt%			65	55		60	50
R143a wt%			33	43		33.4	43.4
R134a wt%						5	5
R601a wt%			0.6	0.6		0.9	0.9
R600 wt%			0.7	0.7			
R600a wt%			0.7	0.7		0.7	0.7
Discharge pressure (bar)	15.46	14.07	16.71	16.71		16.25	16.13
Discharge temperature (°C)	78.8	120.3	69.3	69.3		71.2	72.8
COP (system)	1.56	1.67	1.44	1.44		1.44	1.46
Capacity (kW/m3)	839	839	774	774		746	752
Glide in evaporator (°C)	0.1	0	1.4	1.4		1.9	1.9
Glide in condenser (°C)	0.0	0	1.7	1.7		2.1	2.0

Replacements for R12 in Mobile Air Conditioning

EXAMPLE 7

Blends comprising fluids selected from R134a, R125, 600, 600a and 601a.

The performances of various blends were evaluated in a typical static air conditioning cycle using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	7.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	60.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
COMPRESSOR	
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Table 7. For comparison the performances of R12 and R134a are also shown.

Table 7 - CFC12 Replacements in Mobile Air Conditioning

Refrigerant	R12	R134a	1	2	3	4	5	6	7
R134 wt%			85	87	91	92.2	93	90	92
R125 wt%			12	10.8	6.9	5.5	5	7.8	6
R601a wt%			0.6	0.9	0.7	0.6	0.7	0.9	0.6
R600 wt%			1.8	0.7	0.7	0.7	0.6	1.3	1.4
R600a wt%			0.6	0.6	0.7	1	0.7		
Discharge pressure (bar)	15.7	17.4	18.4	18.3	18.0	17.9	17.8	17.9	17.8
Discharge temperature (°C)	88.4	84.4	83.5	83.8	83.9	83.8	83.9	83.9	83.9
COP (system)	2.45	2.38	2.34	2.34	2.35	2.36	2.36	2.36	2.36
Capacity (kW/m3)	1754	1771	1834	1825	1803	1798	1790	1796	1791
Glide in evaporator (°C)	0	0	1.2	1.2	0.9	0.7	0.7	1.0	0.7
Glide in condenser (°C)	0	0	1.5	1.5	1.0	0.9	0.9	1.2	0.9

Replacements for R12 in Hermetic Refrigeration Equipment

EXAMPLE 8

Blends comprising fluids selected from R134a, R125, 600, 600a and 601a.

The performances of various blends were evaluated in a typical static air conditioning cycle using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	-20.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	45.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
LIQUID LINE/SUCTION LINE HEAT EXCHANGER	
Efficiency	0.3
COMPRESSOR	
Electric motor efficiency	0.85
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Internal fan	0.3 kW
External fan	0.4 kW
Controls	0.1 kW

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Tables 8. For comparison the performances of R12 and R134a are also shown.

Table 8 – CFC12 Replacements in Mobile Air Conditioning

Refrigerant	R12	R134a	1	2	3	4	5	6	7
R134 wt%			86	90.9	82.5	84.6	86.4	90	92.5
R125 wt%			11	7	14	12	11	7	5
R601a wt%			0.9	0.7	0.9	0.6	0.6	0.8	1
R600 wt%			2.1	1.4	2	2.1	1.4	1.4	0.7
R600a wt%					0.6	0.7	0.6	0.8	0.8
Discharge pressure (bar)	11.21	12.06	12.61	12.39	12.88	12.80	12.76	12.43	12.28
Discharge temperature (°C)	127.6	118.2	115.0	116.0	114.2	114.5	115.1	115.6	116.2
COP (system)	1.36	1.34	1.33	1.34	1.33	1.33	1.33	1.34	1.34
Capacity (kW/m3)	698	653	682	670	696	693	690	673	664
Glide in evaporator (°C)	0	0	1.3	0.9	1.6	1.3	1.2	1.0	1.0
Glide in condenser (°C)	0	0	1.8	1.2	2.1	1.7	1.6	1.3	1.2

Replacements for R22 in Room Air Conditioning

EXAMPLE 9

Blends comprising fluids selected from R134a, R125, 600, 600a and 601a.

The performances of various blends were evaluated in a typical static air conditioning cycle using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED	10 kW
EVAPORATOR	
Midpoint fluid evaporation temperature	7.0 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C
CONDENSER	
Midpoint fluid condensing temperature	45.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C
LIQUID LINE/SUCTION LINE HEAT EXCHANGER	
Efficiency	0.3
COMPRESSOR	
Electric motor efficiency	0.85
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82
PARASITIC POWER	
Indoor fan	0.3 kW
Outdoor fan	0.4 kW
Controls	0.1 kW

The results of analysing the performances in an air-conditioning unit using these operating conditions are shown in Tables 9. For comparison the performances of R22 and R407C are also shown.

Table 9 - Replacements for R22 especially in fixed orifice expansion units

Refrigerant	R-22	R407C	1	2	3	4	5
R134a wt%			42.2	44.3	46.3	47.8	49.3
R125 wt%			55	53	51	49	48
R601a			0.8	0.9	0.6	0.8	1
R600			0.8	1	1.4	1.5	1
R600a			1.2	0.8	0.7	0.9	0.7
Discharge pressure (bar)	17.91	19.30	16.05	15.78	15.64	15.37	15.27
Discharge temperature (°C)	104.7	92.5	78.3	78.6	78.7	78.9	79.1
COP (system)	2.49	2.47	2.48	2.48	2.49	2.49	2.49
Capacity (kW/m3)	3067	3172	2671	2635	2619	2580	2566
Glide in evaporator (°C)	0	4.8	4.0	4.1	3.7	3.9	4.1
Glide in condenser (°C)	0	4.7	3.8	3.9	3.7	3.9	4.0

Replacements for R 502 in Low Temperature Refrigeration

EXAMPLE 10

Blends comprising fluids selected from R125, R143a, R134a, R600a, R600 and R600a

The performances of various blends were evaluated in hermetic refrigeration cycle typical of that used in some frozen cabinets using the NIST CYCLE D program. The modelling conditions are given below.

COOLING DUTY DELIVERED
    10 kW

EVAPORATOR

Midpoint fluid evaporation temperature	-35 °C
Superheating	5.0 °C
Suction line pressure drop (in saturated temperature)	1.5 °C

CONDENSER

Midpoint fluid condensing temperature	35.0 °C
Subcooling	5.0 °C
Discharge line pressure drop (in saturated temperature)	1.5 °C

LIQUID LINE/SUCTION LINE HEAT EXCHANGER

Efficiency	0.3

COMPRESSOR

Electric motor efficiency	0.85
Compressor isentropic efficiency	0.7
Compressor volumetric efficiency	0.82

PARASITIC POWER

Internal fan and defrost	0.3 kW
External fan	0.4 kW
Controls	0.1 kW

The results of analysing the performances in fridge-freezer unit using these operating conditions are shown in Table 9. For comparison the performances of R12 and 134a are also shown.

Refrigerant	R502	R22	1	2	3	4	5	6	7	8
R125 wt%			65	55	60.5	63.9	60.5	62.4	60	50
R143a wt%			33	43	37	34	37	35	33.4	43.4
R134a wt%									5	5
R601a wt%			0.6	0.6			0.6	0.6	0.9	0.9
R600 wt%			0.7	0.7	1	1.2	1	1.3		
R600a wt%			0.7	0.7	1.5	0.9	0.9	0.7	0.7	0.7
Discharge pressure (bar)	15.46	14.07	16.71	16.71	16.76	16.90	16.50	16.46	16.25	16.13
Discharge temperature (°C)	78.8	120.3	69.3	69.3	105.4	104.7	107.3	107.1	71.2	72.8
COP (system)	1.56	1.67	1.44	1.44	1.09	1.09	1.08	1.08	1.44	1.46
Capacity (kW/m3)	839	839	774	774	675	679	651	647	746	752
Glide in evaporator (°C)	0.1	0	1.4	1.4	0.9	0.8	2.7	2.9	1.9	1.9
Glide in condenser (°C)	0.0	0	1.7	1.7	0.9	0.8	1.9	2.0	2.1	2.0

Table 10